U.S. DEPARTMENT OF THE INTERIOR
NATIONAL BIOLOGICAL SERVICE

INFORMATION AND TECHNOLOGY REPORT 5

AN ECOLOGICAL FRAMEWORK FOR MONITORING SUSTAINABLE MANAGEMENT OF WILDLIFE:

A NEW MEXICO FURBEARER EXAMPLE

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SEPTEMBER 1996

AN ECOLOGICAL FRAMEWORK FOR MONITORING SUSTAINABLE MANAGEMENT OF WILDLIFE:

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An Ecological Framework for Monitoring Sustainable Management of Wildlife: A New Mexico Furbearer Example

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Abstract: Understanding use relative to availability is necessary to manage wildlife harvest sustainably. We used ecological zones (ecozones) as a framework for evaluating sustainable extraction and for making management decisions concerning 23 furbearing mammal species in New Mexico. We selected an ecological classification scheme, reviewed technical literature, mapped species distribution among ecozones, assessed harvest, estimated sustainable extraction thresholds (levels that trigger management review) where possible, and organized all information in a format with potential application to managing other wildlife. Technical literature review of 70 key words and species names identified 534 citations regarding furbearers in ecozones shared by New Mexico and adjacent states; 260 publications contained pertinent information. We used geographic information system (GIS) software to map estimated occupied habitat by ecozone. Species richness patterns indicated foci for future multiple-species research. This GIS mapping could support interjurisdictional application. We found demographic information necessary to estimate sustainable extraction thresholds only for bobcat (*Lynx rufus*) and red fox (*Vulpes vulpes*). However, conflicting demographic data indicated these estimates could be misleading. We attempted to contact 755 furbearer licensees during the 1991-92 fur season of whom 6.4% were surveyed by journal, 62.5% by mail, 15.6% by telephone, and 15.5% by personal interview. Generally, reported furbearer harvest was consistent with species-ecozone combinations expected from maps of estimated occupied habitat. Our literature synthesis, distribution maps, demographic review, and survey evaluation prepared a substantial ecological baseline for future resource planning. This process is a defensible, proactive approach for responsible management agencies to use to obtain interim ecological perspective while developing more detailed biological data bases for a variety of species.

Key words: demographics, ecological, furbearers, mammals, New Mexico, species distribution, sustainable management

Introduction

Wildlife management is primarily the optimization of the consumptive or appreciative (recreational viewing, knowledge of presence) uses of a resource for humans (Filion 1980; Savidge and Zeisenis 1980). To provide wildlife populations as a renewable natural resource for consumptive use, managers have three choices: (1) mimic natural population sizes, (2) increase population sizes through manipulation, or (3) reduce population sizes in some way. Regardless of which option is chosen, management schemes for extractive use (forms of harvest or killing) of wildlife rest on the assumption that resource extraction is sustainable at some general level over time (Filion 1980; Savidge and Zeisenis 1980; Bailey 1984; Robinson and Bolen 1989). Although sustainable use of resources is not a new concept, it continues to receive considerable attention as a conservation principle (Holt and Talbot 1978; Budowski 1984; Taylor et al. 1987; Turner 1988; Robinson and Redford 1991; Kessler et al. 1992; Meffe and Carroll 1994).

Methods for determining sustainable yields are numerous and complex and have long been debated, especially in fisheries (Schaefer 1954; Roedel 1975; Talbot 1975; Caughley 1977; Larkin 1977; Sissenwine 1979; Healey 1984; Barber 1988). Nonetheless, the effort of scientists devoted to modeling sustainable resource use thus far supports continued application to management of wildlife populations.

Regardless of objective or strategy, sustainable management of wild, living resources rests on assumptions about removal relative to resources available for removal without long-term depletion (Caughley 1977; Holt and Talbot 1978; Shaw 1991). Furthermore, animal populations and the usable resources they provide differ among ecological circumstances (Verner et al. 1986; Ricklefs 1988; Morrison et al. 1992). Techniques for sampling populations and for determining ecological parameters have been described extensively (Schemnitz 1980; Bookhout 1994).

From the long history of wildlife harvest worldwide, one may assume that extensive population and use information about harvested populations of wildlife is organized in ecological context. Although this is true of some wildlife (notably some fishes, many ungulates, and waterfowl), little or no such material exists for other harvested species (most furbearers, reptiles, and amphibians). Modeling sustainable extraction may be considered too complex for all but widely harvested species. Also, the influence of political and jurisdictional boundaries often precludes management within relevant ecological boundaries.

A deficiency of extraction versus availabile information in ecological context is not an indictment of harvest programs; many harvest programs have long histories of use without depletion. Rather, this deficiency indicates that resource management can be improved through better understanding of the factors underlying harvest and its effect on populations. The public should and will expect more of this improvement from wildlife managers responsible for public trust resources.

Debate will continue over fine-tuning extraction to ecological constraints but should not be at the expense of wildlife. Resource managers should use interim measures to efficiently and economically focus on thresholds of species harvest (Quinn et al. 1990) that warrant their attention to review consistency with sustainability. A conservative estimate of population size and sustainable yield rate can be used to calculate a sustainable extraction threshold (deterministic level set conservatively enough to account for stochastic population fluctuations yet trigger timely management review). When estimated amount of harvest exceeds sustainable thresholds, harvest procedures and allocations among licensees must be reviewed.

We examine the foundation for multiple species harvest, and we identify and describe management that is based on ecological divisions of the landscape. We demonstrate a proactive approach for organizing information, identifying data deficiencies, and recognizing new knowledge necessary for continuing wildlife harvest under more intense scrutiny.

Hypothesis and Objectives

Given the premise that existing harvest programs are conducted with knowledge of sustainable extraction, we hypothesized that sustainable removal levels for furbearers can be estimated for distinct ecological zones (ecozones) within limits defined by sufficient existing demographic information to guide management and research decisions.

We conducted our study from August 1990 through December 1992 to

- estimate current distribution of 23 furbearer species in New Mexico and to redefine their ranges in terms of 10-20 ecological subdivisions based on generally accepted biotic communities;
- compile a synthesis of technical literature about estimated demographic parameters and sustainable harvest levels of species by ecozone;
- estimate sustainable extraction levels of 23 species as possible from available demographic information relative to ecozones the species inhabit;
- evaluate the harvest survey of the New Mexico Department of Game and Fish for its usefulness to estimate furbearer harvest and to provide comparative data based on ecozones; and
- identify quantitative extraction levels, a harvest survey procedure, and management considerations for evaluating the entire furbearer resource on an ecozone basis.

The New Mexico Resource Example

New Mexico Furbearers

New Mexico has more than 20 species of furbearers; 17 of these species are harvested for pelts and have been a substantial economic and aesthetic resource. Through the 1980's, trappers in New Mexico annually harvested 50,000 or more pelts with a value of $1.5 million (New Mexico Department of Game and Fish, unpublished annual harvest summaries). Extent and value of appreciative uses are not documented. Assessments of other extractive uses such as illegal harvest, roadkills, and legal hunting under general licenses (of some furbearer species) are difficult.

The New Mexico Department of Game and Fish manages wildlife within the state (New Mexico Department of Game and Fish 1967). Before the late 1970's, the New Mexico Department of Game and Fish had only limited furbearer management. However, the increased fur harvest of the late 1970's spurred nationwide interest in managing furbearers as a renewable natural resource (Melchoir et al. 1987).

Past furbearer management by the New Mexico Department of Game and Fish focused primarily on regulations and estimations of harvests with data from mail surveys. No data were compiled to determine how annual extractive uses related to the sizes of furbearer populations in the state or in an ecological region. Although furbearers seemed to have sustained their populations for long terms under this management, the estimation of harvests with data from mail surveys (potential user-response bias and no corroborative biological data) is not a biologically adequate foundation of wildlife management regardless of population sizes or interest in harvest.

We assessed an ecologically based management framework for 23 species. Twenty-two species were statutory or regulatory furbearers in New Mexico. We also included the Virginia opossum (*Didelphis virginiana*), which occurs in New Mexico and is not a statutory furbearer but is commonly considered a furbearer. We did not include the black-footed ferret (*Mustela nigripes*), a statutory furbearer in New Mexico, because it is a federally and state listed endangered species and thus not a candidate for harvest. Seventeen of the 23 assessed species are annually harvested for their pelts or for other purposes; the remaining species are not subject to regulated harvests.

New Mexico Landscape

We evaluated our proposed ecological framework for the management of furbearers in all of New Mexico. The state has an area of 311,478 km^2, of which almost half is privately owned. A third is owned by the Federal Government and administered primarily by the U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. Department of Defense. The remaining land is split between state and Native American tribal ownership (McAllister 1986). The population of New Mexico is 1.51 million people (U.S. Bureau of Census 1992), or almost 5 people/km^2. The population is clustered along the San Juan, Pecos, and Rio Grande drainages (Williams 1986).

Elevations in New Mexico range from 4,011 m at Wheeler Peak in the north to 866 m at Red Bluff Reservoir on the Texas-New Mexico border in the south. Climate varies greatly throughout the state. Northern New Mexico has cool, short summers and long, cold winters, whereas southern New Mexico has mild winters and long, hot summers (Bennett 1986; Dick-Peddie 1993). Precipitation in most of

New Mexico averages less than 50 cm/year although higher elevations may receive as much as 1 m (Bennett 1986).

The ecological regions of New Mexico are diverse (Brown 1982; Dick-Peddie 1993). About one-third of New Mexico is grasslands, primarily at the lower elevations throughout the state. Another third of the state is woodlands and forests at the higher elevations. The remaining third of the state is composed of urban areas, farmland, riparian areas, lava beds, scrubland, or sand dunes. Several major river systems include the Rio Grande, Gila, Pecos, Canadian, San Juan, Rio Chama, Rio Puerco, Conchas, and Mora.

Components of the Ecological Framework

Development of an ecologically based sustainable management framework included five steps:

(1) selection of a vegetation-based map to map species distribution by ecozone,

(2) collation of species distribution, habitat, and demographic information about furbearers in New Mexico from existing literature,

(3) delineation of species distribution in ecozones with information from the literature review,

(4) estimation of sustainable extraction thresholds for each species in each ecozone using demographic information from the literature survey, and

(5) survey of licensed trappers by several techniques to estimate furbearer harvest for comparisons with sustainable extraction thresholds .

Ecozone Map Development

Ecozone maps are based on the premise that areas can be divided into ecologically meaningful units based on vegetation and physiogeographic features. We considered an ecozone to be a subdivision of the landscape with vegetation and physical features that comprise distinct habitats for animal species we reviewed.

To select a vegetation community classification system, we reviewed 17 schemes, judging them on two criteria. The system needed to represent recent information and to have a tractable number of zones. A system with six or fewer zones was considered too simple to describe furbearer habitat, and one with more than 20 zones was considered too complex for general management application. We reviewed Merriam (1898), Bailey (1913), Fenneman (1938), Weaver (1938), Dice (1943), Aldrich (1963), Hammond (1964), Kuchler (1964), Hunt (1974), Garrison et al. (1977), Donart et al. (1978), Bailey (1980), Martin and Hutchins (1980), Brown (1982), Ivey (1983), Williams (1986), and Dick-Peddie (1993).

We selected the Dick-Peddie (1993) classification (Fig. 1; reviewed in prepublication form) because of its appropriate amount of detail, its recent development, and its applicability to our area of study. Dick-Peddie's map reflected soil types, elevation contours, and physiogeographic features in describing 16 ecozones (Fig. 1, Table 1) ranging from the smallest Alpine Tundra (297 km^2) to the largest, Plains-Mesa Grassland (69,868 km^2). He revised previous classification systems to include Juniper Savanna and Desert Grassland ecozones. Dick-Peddie used field site visits to verify vegetation boundaries and composition presented in his map. Our use of this recently developed and easily digitized system was consistent with suggestions subsequently made by Koeln et al. (1994) regarding use of available systems rather than developing new systems.

To aid interpretation through computer screen overlays, we included state boundaries, county lines, major roads, rivers, and streams in a geographic information system (ARC/INFO). We assumed a riparian zone (using a GIS buffer) along each major water course by adding a 4-km strip to each side (approximated distance of riparian vegetation influence on furbearer species in major river drainages) to illustrate where we expected distribution of riparian-dependent species to be influenced. The rivers we included in our GIS files for map overlay were the Rio Grande, Gila, Pecos, Canadian, Cimarron, San Juan, Rio Chama, Rio Puerco, Conchas, Hondo, Red, Bonito, Mora, and Mimbres. Other water courses were considered too small for the scale of our mapping. We used the United Nations Educational, Scientific, and Cultural Organization (1973) color classification system for the final version of the map to ease interpretation.

Technical Literature Review

We collated biological and demographic information from existing literature for the basis of mapping species distribution and estimating sustainable

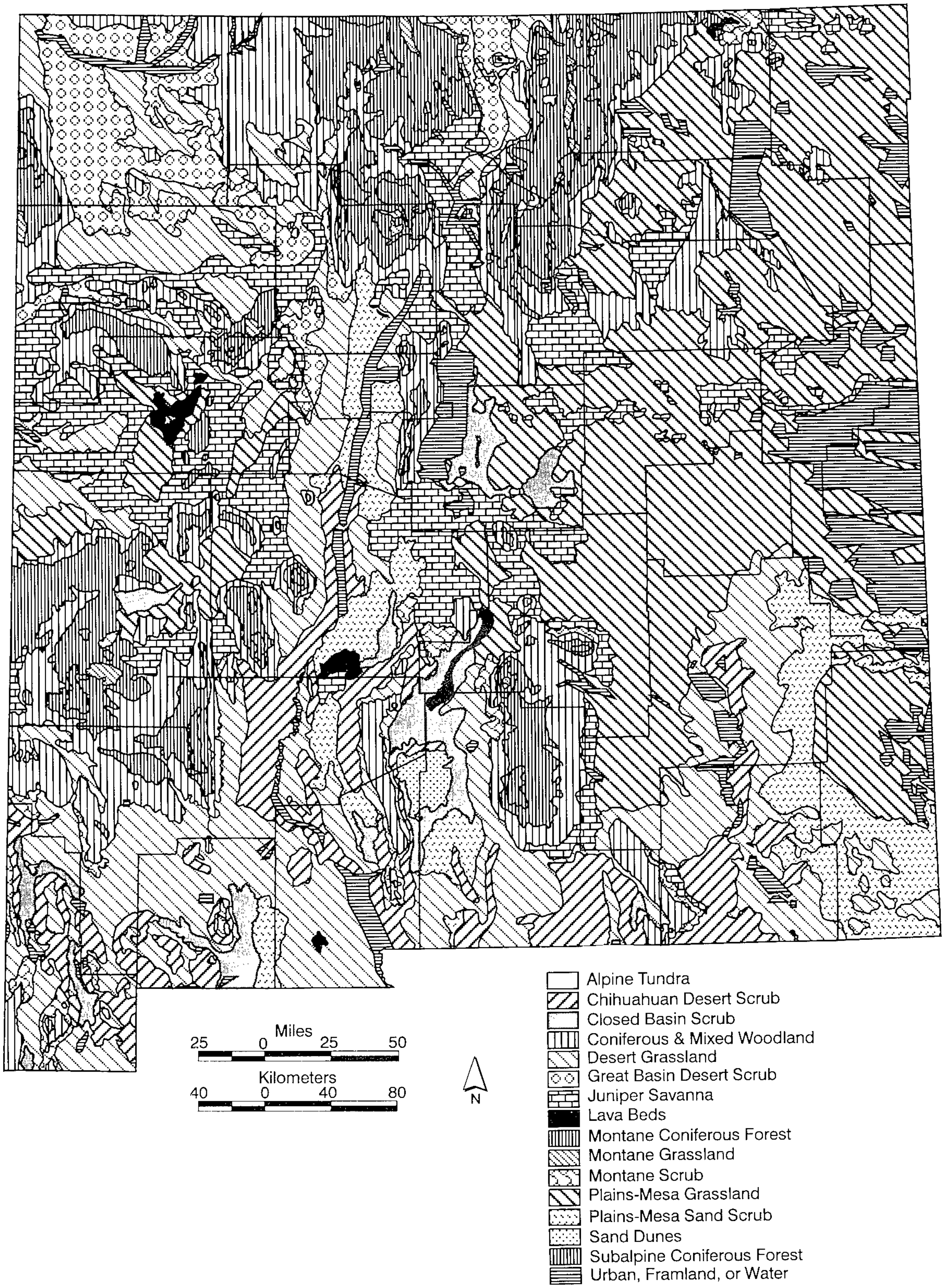

Fig 1. Map showing 16 ecological zones adapted from Dick-Peddie (1993) to describe furbearer distribution in New Mexico.

Table 1. Name, abbreviation, and estimated area for 16 ecozones adapted from Dick-Peddie (1993) for ecological organization of information about furbearers in New Mexico.

Ecozone[a,b]	Abbreviation	Area (km^2)
Alpine Tundra	AT	297
Subalpine Coniferous Forest	SCF	8,756
Montane Coniferous Forest	MCF	23,609
Coniferous and Mixed Woodland	CMW	41,470
Juniper Savanna	JS	30,939
Montane Scrub	MS	3,106
Plains-Mesa Sand Scrub	PMSS	17,059
Great Basin Desert Scrub	GBDS	12,598
Chihuahuan Desert Scrub	CDS	18,845
Closed Basin Scrub	CBS	7,539
Montane Grassland	MG	1,014
Plains-Mesa Grassland	PMG	69,868
Desert Grassland	DG	55,233
Urban, Farmland, or Water	UFW	19,000
Lava Beds	LB	1,190
Sand Dunes	SD	955
Total		311,478

[a]Ecozones are grouped according to forested, scrub, grassland, and other structural types and are listed generally in order from highest to lowest elevation.
[b]Additionally, 28,663 km of riparian area was buffered in the mapping process for predicting some species distributions. That buffered area is sometimes referred to in text as riparian zone.

We used 24 key words and phrases about habitat and demographics in the literature search (Table 2). In consultation with wildlife management personnel at New Mexico Department of Game and Fish headquarters, we assigned ranks to 23 species (Table 2) based on perceived amount of existing information and anticipated inclusion in future harvest. The ranking was used to ensure that we did extraction thresholds. We collected information on species association with location, vegetation, or other components of an ecozone; estimated ranges of each species; estimated minimum and maximum density of each species by ecozone; and sustainable yield rates of each species in an ecozone.

Table 2. Species, habitat, and demographic key words for the literature review of furbearers in New Mexico.

Species key words[a]	
Badger (H)[b]	*Taxidea taxus*
Beaver (L)	*Castor canadensis*
Bobcat (L)	*Felis rufus*[a]
Coati (M)	*Nasua nasua*
Coyote (L)	*Canis latrans*
Ermine (H)	*Mustela erminea*
Fox, gray (H)	*Urocyon cinereoargenteus*
Fox, kit (H)	*Vulpes macrotis*
Fox, red (H)	*Vulpes vulpes*
Fox, swift (H)	*Vulpes velox*
Marten (H)	*Martes americana*
Mink (M)	*Mustela vison*
Muskrat (L)	*Ondatra zibethicus*
Nutria (L)	*Myocastor coypus*
Opossum (L)	*Didelphis virginiana*
Otter, river (M)	*Lutra canadensis*
Raccoon (H)	*Procyon lotor*
Ringtail (H)	*Bassariscus astutus*
Skunk, hog-nosed (H)	*Conepatus mesoleucus*
Skunk, hooded (H)	*Mephitis macroura*
Skunk, spotted (H)	*Spilogale putorius*
Skunk, striped (H)	*Mephitis mephitis*
Weasel, long-tailed (L)	*Mustela frenata*

Habitat and demographic key words		
attrition	ecosystems	natality
birth rates	ecozones	populations
carrying capacity	fecundity	range
census	fur harvest	regulations
conservation	fur resources	reproduction
demographics	habitat	survey
density	longevity	survival rate
distribution	mortality	sustainable

[a]Common and scientific names represent names expected in computer abstracting files; deviation from recent taxonomic terminology is recognized (e.g., *Felis rufus* used here but *Lynx rufus* elsewhere in text.
[b]Letters in parentheses represent high (H), medium (M), and low (L) ranking assigned in consultation with New Mexico Department of Game and Fish to prioritize time spent seeking information.

Data Bases and Keywords

We searched for relevant publications through the Fish and Wildlife Reference Service and New Mexico State University Branson Library by using 10 on-line data bases: Agricola, Biosis Previews, Science Citation Index, Wildlife Review, Fish and Wildlife Reference Service, Zoological Record, Hierarchical Environmental Retrieval for Management and Networking, National Technical Information System, Comprehensive Dissertation Index, and the Commonwealth Agricultural Bureaux Abstracts. We also requested relevant publications from wildlife agencies in Arizona, Colorado, New Mexico, Oklahoma, Texas, and Utah.

not spend inordinate time either reviewing a species with limited future harvest likelihood or searching for an obscure reference for a species with an otherwise large existing information base. We recognized conspecific taxonomy of kit (*Vulpes macrotis*) and swift (*Vulpes velox*) foxes suggested by Dragoo et al. (1990), but these species were separated for information compilation because of their separate treatment in existing literature and separate management in some areas. During key word searches, we used taxonomic names generally used in literature historically, not just those used in this report.

Organization of Information

We cross-referenced literature citations based on the following information: journal or publication, species, ecozone, state or states, author, and subject matter. We maintained the bibliography on ProCite Bibliographic Software, which was specifically designed for handling large bibliographies.

We separated publications into three categories. Primary literature included publications about demographic information or a high-ranked species (Table 2). Secondary literature concerned a low priority species or was judged to have less valuable information about a moderate priority species. Literature in the third category was omitted from the data base because preliminary review indicated it did not pertain to any of the 23 furbearer species.

To incorporate information from the literature into the ecological framework, we coded publications relative to applicable ecozones from the New Mexico ecozone map (Fig. 1; Table 1). To assign these ecozones, we located the study sites on state maps (Burdett et al. 1990) from literature descriptions, then on vegetation maps. We used information about vegetation maps and plant species distribution from Vines (1960), Kuchler (1964), Bailey (1976), Blankenship and Swank (1979), Brown (1982), Hoffmeister (1986), and Dick-Peddie (1993).

We compared the vegetation for study sites outside New Mexico (but in potentially applicable ecozones) to descriptions of Dick-Peddie's (1993) vegetation zones. Citations were coded to an ecozone if they met two criteria. First, a majority of the vegetation described in the publication matched the vegetation type of the ecozone. Second, climatic conditions or land forms at the study site were similar to those found in New Mexico. Ecozones for study sites in New Mexico were identified by simply locating the site on the map provided in Dick-Peddie (1993). It was possible for study sites described in citations to represent more than one ecozone; in these cases, species associations were assigned to each applicable ecozone.

Mapping Species Distribution in Ecozones

Our ecozone approach to distribution avoided many of the limitations described by Scott et al. (1993) for dot distribution, grid-based, range, and hybrid dot distribution-range maps. Because our approach was based on animal species associations with mapped habitat categories, we were able to exclude areas of presumed inappropriate habitat from the species range. We mapped species into ecozones or portions of ecozones based on: (1) information from the literature review; (2) information from U.S. Bureau of Land Management and U.S. Department of Agriculture Animal Damage Control Program; (3) museum records; (4) interviews with wildlife professionals at New Mexico State University, New Mexico Department of Game and Fish, and University of New Mexico; (5) species observations and roadkills reported by resource professionals; and (6) draft map reviews by species experts.

Literature Review

Publications compiled from the literature review provided furbearer background information such as distribution data, habitat description, food habits, behavior, and reproductive habits. We used this information to identify habitat associated with New Mexico furbearers.

After we identified a species' habitat, we related the habitat to a specific ecozone. We did this by comparing key plants and other features found in the habitat description to Dick-Peddie's ecozones. References particularly helpful with this step were Chapman and Feldhamer (1982), Deems and Pursley (1983), Allen (1987), and Novak et al. (1987). Species habitat preferences for the same ecozones shared with surrounding states came from Hoffmeister (1986) for Arizona, Zeveloff (1988) for Colorado, Caire et al. (1989) for Oklahoma, Schmidly (1984) for Texas, and Durrant (1952) and Armstrong (1982) for Utah. Schmidly (1977) described species distribution in Mexico that supplemented our information base for species in Chihuahuan Desert biotic communities.

In some instances, we categorized species to ecozones by using specimen records from literature. Findley et al. (1975) provided general specimen localities (mapped dots) for badger (*Taxidea taxus*), coati (*Nasua nasua*), ermine (*Mustela erminea*), gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), mink (*Mustela vison*), marten (*Martes americana*), raccoon (*Procyon lotor*), and red fox (*Vulpes vulpes*). Bailey (1931) provided historical species distribution for New Mexico. We also consulted specimen records from museums at New Mexico State University at Las Cruces, Eastern New Mexico University at Portales, Western New Mexico University at Silver City, and The Museum of Southwestern Biology at the University of New Mexico in Albuquerque. We used general range map data carefully because of the potential for dot placement error.

Species Distribution Mapping

We used geographic information system (GIS) software (ARC/INFO) to combine the ecozone map with distribution data in a two-step process. First, we manually digitized records; second, we visually selected ecozone polygons that encompassed data records. If an animal was documented as present in a county, it was assumed to be present in all ecozone segments encompassing appropriate habitat in that county. Where documented species occurrence in an ecozone segment was truncated at a county line by preliminary GIS processing, we mapped distribution in that segment to its boundary.

Findley (1987) and professionals from Animal Damage Control and U.S. Bureau of Land Management helped identify the limits of water course use by furbearers (beaver [*Castor canadensis*], mink, muskrat [*Ondatra zibethicus*], and raccoon). These species were not mapped in the Urban, Farmland, and Water ecozone because it was impossible to accurately plot species in the generally small inclusions of suitable habitat within this collective type.

We defined three categories of ecozones relative to species distribution. Ecozones were considered primary if they closely resembled documented habitat for a species. In a primary ecozone, an animal can routinely find food and shelter and will be able to reproduce. A species may be found occasionally or seasonally in secondary ecozones but will not be as routinely prevalent as in primary ecozones. Species with strong affinity for hydrologic features and vegetation associated with major water courses were associated with a generalized riparian zone. The scale of our mapping prevented inclusion of small, scattered wetland or riparian areas such as ditches, canals, or ponds.

We did not truncate species distribution lines at artificial borders (county lines). Rather, we allowed distribution lines to follow the natural boundary of an ecozone segment to a biologically defined limit of distribution. The only distribution lines that do not represent ecozone boundaries are those representing physiogeographic barriers.

Observation and Roadkill Survey

As part of our map refinement we asked wildlife professionals throughout New Mexico to record furbearer sightings and roadkills from August 1991 to June 1992. We requested species name, location, habitat description, and degree of identification certainty. We provided a list of the scientific and common names of the 23 species of interest as well as a sketch of different skunk striping patterns reproduced from Schmidly (1984). We sent the survey to resource agency wildlife biologists, Fishery and Wildlife Sciences Department faculty and graduate students at New Mexico State University, Biology Department personnel at the University of New Mexico, and other resource professionals statewide. We asked each survey recipient to distribute copies of the survey to other wildlife professionals. Observations listed as uncertain were not used. Reported locations (detailed in Thompson et al. 1992b) were added to the species distribution records and aided final distribution decisions.

Draft Map Reviews

We sent drafts of the species distribution maps to 51 wildlife professionals for review. These professionals represented resource agencies in Arizona, Colorado, New Mexico, Oklahoma, and Texas; New Mexico Natural Heritage Program; Navajo Natural Heritage Program; and wildlife and biology faculty at Angelo State University, Colorado State University, New Mexico State University, Sul Ross State University, Texas A&M University-College

Station, Texas Tech University, University of Colorado, and the University of New Mexico. We received responses from 28 of these reviewers and incorporated that information into second drafts of the maps. Second drafts were sent to five expert reviewers, of whom four responded.

We ultimately plotted estimated distribution of suitable occupied habitat for 21 of 23 furbearer species; kit fox and swift fox were plotted together as desert foxes. No maps were plotted for nutria (*Myocastor coypus*) (scattered, poorly documented occurrence) or river otters (*Lutra canadensis*) (thought to be extirpated, Findley 1987). We plotted five riparian-dependent species (beaver, mink, muskrat, opossum, and raccoon) as present only adjacent to major water courses. Expert review of second draft maps identified additional refinements in distribution for beaver, coati, desert foxes, red fox, ermine, mink, muskrat, opossum, and hog-nosed (*Conepatus mesoleucus*) and hooded (*Mephitis macroura*) skunks. We did not verify the final species distribution map with field work. We acknowledge that errors exist in such a mapping approach, but effective verification requires years (Block et al. 1994) and was beyond the scope of our work.

From the final species distribution maps, we estimated total occupied habitat for each species. For riparian species, we calculated total stream length because abundance estimates for those species are typically reported in linear units. We used these values to determine population estimates as part of the calculation of sustainable extraction threshold.

$$\frac{\text{animals}}{\text{unit length}} \times \text{total estimated length}$$

Estimating Sustainable Extraction Thresholds

Our next step was to estimate a sustainable extraction threshold for each species in each ecozone (expressed as total animals per ecozone). Our intent here was to conservatively approximate the number of animals that may be removed annually from a population in each ecozone without reducing the population's ability to sustain itself (Storm and Tzilkowski 1982). We acknowledged that available data and the concept of sustainability were imperfect; thus these estimates would yield thresholds of attention (i.e., levels that trigger specific management review) rather than absolute limits of harvest. This calculation was the step that united the literature review with ecozone map development.

Using the data base compiled from our previous literature review, we organized citations by species and extracted the following information by ecozone: sustainable yield rate, adult pregnancy rate, juvenile pregnancy rate, adult survival rate, juvenile survival rate, fecundity, average litter size, recruitment rate, fall density, and sex ratios.

We assembled these data in a species-by-species spreadsheet for subsequent calculations of sustainable extraction thresholds. This number of parameters relative to 17 ecozones yielded a large number of cells in the matrix for which we expected empty cells among species. Empty cells represented nonapplicable zones, data deficiencies, or parameters unavailable to us in attempting to summarize sustainability estimates. Not all parameters were necessary for our estimates; those other than sustainable yield rate and fall density were considered only if these two basic parameters were not available.

To calculate a sustainable extraction threshold for a species in an ecozone, we used the following formula:

$$SET = PD \times H \times SY,$$ where

SET is sustainable extraction threshold,
PD is population density (animals/km^2),
H is estimated occupied habitat (km^2), and
SY is sustainable yield rate (%).

For each species, we used minimum and maximum population densities to estimate a range of population values for each ecozone. We found a variety of sustainable yield rates during literature review but used the most conservative rates for each ecozone to calculate threshold values for each species to be consistent with representing thresholds of attention.

Evaluating Harvest Survey Alternatives

We assessed the effectiveness of four survey formats (journal, mail, telephone, and personal interview) to estimate the harvest of 17 species (those legal for annual fur season) among ecozones for comparison to sustainable extraction thresholds. Our surveys for the 1991-92 fur season substituted for the mail survey usually conducted by New Mexico Department of Game and Fish.

Sample Determination

The sample population was adults and juveniles (less than 18 years old) who had purchased a trapper's license for the 1991-92 season prior to 15 February 1992. The trapping season ended on 15 March 1992. In New Mexico at the time of this research, a "trappers license" was the statutory name of the license required for furbearer harvest; licensees are allowed to use a variety of harvest methods in addition to traps.

We divided the licensees into adults and juveniles and then performed a systematic selection process. We determined the desired sample for each survey from the expected number of contacts needed to obtain statistically adequate responses (10% of total licensees) for each survey type given differing degrees of personal communication among survey types (response rates were estimated from past interview experience at the New Mexico State University Experimental Statistics Department and responses to New Mexico Department of Game and Fish mail surveys).

The number of licensees on a composite list was divided by desired sample size to determine the numeric interval to select names from the list. For example, if the desired initial sample was 70 of 700 licensees, then every 10th licensee was selected for the survey. A random number was used to select the first person; the interval of selection was used to choose the rest of the sample. This process yielded representative samples stratified among age and geographic distribution of licensees. Our procedures incorporated advantages of each survey type as discussed by Goudy (1976), National Center for Health Services Research (1977), Dillman (1978, 1983), Groves and Kahn (1979), Bradburn (1983), and Sudman (1983). Detailed descriptions of survey questions and forms used for all sampling were reported by Thompson et al. (1992b).

Journal Survey

For the journal survey, we asked participants to record their harvest throughout the fur season. Licensees surveyed by this format were chosen by combining a list of 1990-91 licensees with a list of people who purchased a 1991-92 license prior to 15 August 1991. This identified survey participants and allowed us to distribute survey materials prior to the 1991-92 fur harvest season. We requested licensees to record species harvested, date and location of the harvest, and dominant vegetation at the harvest site. We also included a state road map for each participant to mark harvest locations. At the end of the season, we requested that each participant return the journal, map, and a brief questionnaire in a postage-paid envelope provided. All licensees in this group who did not return their journals were contacted by telephone. We used their telephone responses to supplement the journal survey.

Mail Survey

We contacted participants in the mail survey after the fur season closed on 15 March 1992. We asked licensees to provide essentially the same information that we requested in the journal survey. About a month after we sent the first mailing, we sent a reminder and a second set of survey materials to the nonrespondents. We telephoned 25% of the licensees who did not respond to either of the questionnaires. We asked them for the same information that the questionnaire solicited and for the reason they had not responded to the earlier questionnaires.

Telephone Survey

We sent a letter to the selected licensees 1 week prior to the survey date to explain the purpose of the survey. The letter also contained an ecozone map of the state and a survey form requesting the standard harvest information to expedite our data collection. The dialogue we used in these contacts was designed to be objective and professional while maintaining a personal tone (Dillman 1978). If we did not contact a participant after six attempts, we sent a mail survey to collect the data.

Personal Interviews

We made five attempts at different times of day to schedule an appointment with each potential participant in the personal interview survey. If this was not possible, we tried to contact the person when we traveled to his or her area. The dialogue we used was designed to be objective, unbiased, and flexible (Dillman 1978, 1983; Weinberg 1983), and it solicited the standard harvest information. If a person was not contacted for an interview, we sent them a mail survey form to collect the data.

Data Treatment

To estimate statewide harvest among survey types, we calculated an average harvest for each species per respondent and then multiplied the average harvest by the total number of licensees to estimate the size of the harvest. This approach assumed that harvest by individual nonrespondents was represented in the range of values estimated for initial respondents and from follow-up contacts with initial nonrespondents. Values used in calculations accounted for differences in responses between respondents to initial contacts and follow-up contacts by proportionally applying the different harvest rates across all licensees.

To determine if there were differences in harvest reporting for the different survey types, we estimated the total harvest for several species from the data for each survey type. Analysis of variance tables for four widely harvested species (bobcat, coyote [*Canis latrans*], gray fox, and raccoon) from the four survey types were used to analyze differences in survey types (SAS Institute, Inc. 1990).

Statistical evaluation of survey types took precedence over estimation of harvest for each species among all ecozones. Because licensees were divided into different survey types, sample size was insufficient to estimate harvest among ecozones for all survey types. Reported harvest distribution among ecozones was compared to mapped ecological distribution of each species. For the 17 species among 16 ecozones (riparian excluded), there were 272 cells for classifying harvest of which 118 cells represented combinations not considered possible because of inapplicable habitat associations among all species.

Attributes of the Assembled Framework

Literature Synthesis

We identified 534 literature citations as potentially applicable to furbearers in New Mexico ecozones. Of these, there were 205 (38.4%) publications about species habitat and distribution and 157 (29.4%) about demographics. At least one aspect of the project was addressed in 260 (48.7%) publications initially identified through key word categorizations. We found no publications with information specific to ecozones for 15 of the 23 furbearer species. Further results of the literature review are discussed in subsequent sections regarding species distribution in ecozones and demographic information base. Detailed lists of literature citations, divided by subject, that were consulted during this review were reported by Thompson et al. (1992b).

Species Distribution in Ecozones

A simple matrix of furbearer distribution based only on county boundaries revealed a diverse array of distribution patterns among species in New Mexico's 33 counties (Fig. 2). These species-by-county records compiled from literature review, museum records, resource agency reports, and the observation and roadkill survey represent the extent of information synthesis generally available to wildlife agencies for multiple species. Thirty-four participants in the observation and roadkill survey reported more than 500 sightings of 18 species (Fig. 2). These reported sightings provided scattered verification of species-by-county occurrence. Most records, as expected, were for relatively common or easily seen and recognized species like coyote, gray fox, raccoon, and striped skunk *Mephitis mephitis* (Fig. 2). Records (museums plus New Mexico Department of Game and Fish harvest reports) for nutria were too old, scattered, or incomplete to provide meaningful perspective on current distribution in New Mexico. No records were found concerning recent occurrence of river otter in New Mexico.

A matrix of primary and secondary ecozone associations for each species demonstrated substantial furbearer species representation within each ecozone (Table 3). Only coyote was associated with every ecozone. There were 14 species with primary habitat associations in five or more ecozones. At this stage, general ecozone associations were depicted, but patterns were still misleading among species. Thus, an all or none perspective was depicted for each species-ecozone combination (Table 3), even though species distribution in an ecozone may not necessarily include all portions (fragments) of a zone because of abiotic factors (temperature, precipitation, etc.). Data from the observation and roadkill survey corroborated 67 of 183 (36.6%) ecozone assignments (Table 3).

Examples of final distribution plots illustrate differing ecological patterns for a peripheral,

	Bernalillo	Catron	Chaves	Cibola	Colfax	Curry	De Baca	Dona Ana	Eddy	Grant	Guadalupe	Harding	Hidalgo	Lea	Lincoln	Los Alamos	Luna
Badger	*	*	*3	*	*3	*	*1	*2	*1	*	*	*	*2	*	*	*	*2
Beaver	*	*	*		*1		*	*2			*				*		
Bobcat	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*1	*	*
Coati		*								*			*2				
Coyote	*	*7	*6	*3	*21	*	*	*52	*	*7	*2	*2	*19	*1	*3	*	*7
Ermine	*				*												
Fox, gray	*	*	*5	*	*		*	*2	*4	*1	*	*	*	*	*15		*
Fox, kit	*	*	*	*		*	*	*	*	*	*	*	*	*	*		*
Fox, red	*	*	*	*	*1			*	*1					*			
Fox, swift			*			*	*	*	*		*	*		*	*		*
Marten					*												
Mink					*												
Muskrat	*	*	*	*	*			*7	*1		*				*		
Nutria																	
Opossum	*						*	*1					*				
Otter																	
Raccoon	*	*	*11	*	*4	*	*	*3	*1	*2	*	*	*2	*	*4	*	*
Ringtail	*	*	*	*	*		*	*	*1	*		*	*1	*	*4		*
Skunk, hog-nosed	*	*	*1	*				*	*1	*	*	*	*		*2		
Skunk, hooded		*							*1	*	*		*		*2		*1
Skunk, spotted	*	*	*		*			*1	*1	*	*		*		*1		*
Skunk, striped	*	*3	*3	*	*9	*	*	*5	*3	*10	*	*	*1	*	*27		*
Weasel, long-tailed	*	*	*	*	*1	*		*1	*1	*			*	*	*	*	

	McKinley	Mora	Otero	Quay	Rio Arriba	Roosevelt	Sandoval	San Juan	San Miguel	Santa Fe	Sierra	Socorro	Taos	Torrance	Union	Valencia
Badger	*	*	*	*	*2	*	*	*	*	*	*1	*4	*	*1	*3	*
Beaver	*	*	*	*	*		*	*15	*	*		*13	*		*	*1
Bobcat	*	*	*	*	*3	*	*	*	*	*	*	*3	*1	*	*	*
Coati																
Coyote	*	*2	*7	*	*17	*	*	*1	*	*	*1	*32	*	*14	*16	*
Ermine					*		*	*	*	*			*			
Fox, gray	*	*	*		*		*	*1	*	*	*	*3	*	*2	*	*
Fox, kit	*		*		*			*			*	*		*		*
Fox, red	*	*			*	*		*	*			*1	*	*	*1	
Fox, swift	*	*	*	*		*		*							*	*
Marten		*			*				*	*			*			
Mink		*			*			*	*	*		*1	*			*
Muskrat					*		*	*	*			*2	*			*
Nutria																
Opossum				*								*2				*
Otter																
Raccoon	*	*	*2	*	*	*	*	*2	*	*	*	*3	*	*	*2	*
Ringtail		*	*	*	*	*	*		*	*	*	*	*	*	*	*
Skunk, hog-nosed	*		*							*	*	*		*		*
Skunk, hooded																
Skunk, spotted	*	*	*		*		*	*	*	*	*	*		*	*	*
Skunk, striped	*	*	*5	*	*1	*	*	*	*	*	*	*2	*	*1	*6	*
Weasel, long-tailed	*	*	*	*	*	*	*	*	*	*	*	*2	*	*	*	*

Fig 2. General occurrence (asterisk indicates species found in that county) matrix for 23 furbearer species among 33 New Mexico counties as documented by literature, museum records, and resource agency reports. Numbers indicate specimens detected during the 1991-92 observation and roadkill survey; shading represents museum records for a species in New Mexico.

Table 3. Ecozones classified as primary (P) and secondary (S) habitat for 23 furbearer species in New Mexico.

	Habitat assignment by ecozone[a]																
	Wooded					Scrub-shrub lands					Grassland						
Species	AT	SCF	MCF	CMW	JS	MS	PMSS	GBDS	CDS	CBS	MG	PMG	DG	UFW	LB	SD	R
Badger		S	S^b	S^b	P^b	S	P	P	P^b	P	S	P^b	P^b	S^b	S	S	
Beaver														S^b			$P^{b,d}$
Bobcat		P	P	P	P^b	P	S^b	P^b				S	S		P		$S^{b,c}$
Coati			P	P^b	P	S			S	S		S	S				P^c
Coyote	P	P	P^b	P^b	P^b	P^b	P^b	P^b	P^b	P^b	P	P^b	P^b	P^b	P^b	P^b	$P^{b,c}$
Ermine		P	P	S		P					P						
Fox, gray				P^b	P^b	P	P		S^b	P		S^b	S^b		P		$P^{b,c}$
Fox, kit					P^b		P	P	P^b	P^b			P^b			P	
Fox, red	S	P	P	P			S	S	S				S	P			
Fox, swift												P^b	P				
Marten	P	P															
Mink														S^b			P^d
Muskrat														S^b			$P^{b,d}$
Nutria														S			P^d
Opossum				S	S							S	S	S^b			$P^{b,e}$
Otter														S			P^d
Raccoon		S	S	S	S	S	S	S	S	S^b	S	S^b	S^b	S^b		S	$P^{b,e}$
Ringtail		S	S	P	P^b	P^b		P	P			P	P		S		P^c
Skunk, hog-nosed				P	P^b	P^b			P	P			P	S^b	P	P	
Skunk, hooded				P					P^b	P		P	P	S			P^c
Skunk, spotted			P	P	P^b	P^b	P	P	P			P	P				
Skunk, striped	S	S	P^b	P^b	P^b	P^b	P	P	P^b	P	P	P^b	P^b	P^b	P	S	$P^{b,c}$
Weasel, long-tailed	P	P	P	P	P	P	P		P		P	P	P	P^b			

[a]Ecozone abbreviations are defined in Table 1.
[b]Represents ecozone assignments where species were detected during the observation-roadkill survey (September 1991-May 92).
[c]Species is not riparian dependent but occupies riparian areas and adjacent upland ecozone. Riparian areas were not included in area total for population analysis.
[d]Species is classified as riparian dependent but also occupies UFW and other ecozones where water is found. Only riparian extent (linear) was used for demographic analysis.
[e]Species is classified as riparian dependent but also occupies adjacent ecozones. Only riparian extent (linear) was used for demographic analysis.

nomadic species like coati (Fig. 3); lower elevation grassland and shrubland specialists like desert foxes (Fig. 4); terrestrial generalists like gray fox (Fig. 5) and hog-nosed skunk (Fig. 6); and riparian species like raccoon (Fig. 7). These distributions predict current areas of potential occurrence at ecozone resolution. Our distribution maps were constrained by information that could be generated from 1:1,000,000 scale data bases. Many landscape features and microhabitat sites critical to furbearer habitat, such as rocky outcrops, cliffs, small watering sites, and arroyos (dry washes), could not be shown at this resolution. Localized discrepancies undoubtedly exist for each species.

Species Richness and Estimated Occupied Habitat

The projected area of greatest furbearer species richness was concentrated in central and west-central New Mexico (Fig. 8). This richness is primarily associated with Juniper Savanna and Coniferous and Mixed Woodland ecozones, with as many as 11 furbearer species occupying one portion of one ecozone (Fig. 8). These areas of high species richness can potentially focus research and management efforts because they illustrate locations to contact many species within a small area.

Tabulation of estimated occupied habitat among ecozones revealed that different species were associated with various portions of each ecozone (Table 4). These differences reflected assignment of species to ecozone fragments by applying GIS operations based on ancillary information (elevation, climatic regions) rather than all-or-none assignment to ecozones (e.g., marten is found in Subalpine Coniferous Forest but only in northern New Mexico mountains). Nine species exceeded 100,000 km^2 of estimated primary occupied habitat. Seven ecozones provided primary habitat for eight or more species. Marten had the most limited distribution for a nonriparian species (Table 4), occurring in only two restricted ecozones with an estimated occupied habitat of 6,205 km^2 (68.5% of total area in associated ecozones).

Sustainable Extraction Thresholds

We were largely unsuccessful in finding necessary density and sustainable yield rate information—a deficiency that was the primary reason our basic hypothesis was not supported. Of 534 potentially applicable literature citations, only 45 had specific demographic estimates for pertinent species in relevant ecozones. This lack of information prevented further analysis of the badger, coati, ermine, gray fox, red fox, mink, nutria, opossum, river otter, raccoon, hog-nosed skunk, hooded skunk, spotted skunk (*Spilogale putorius*), striped skunk, and long-tailed weasel.

Although 45 articles contained demographic estimates, they did not provide the information specific to ecozones. Thus, detailed analysis was not possible for beaver, kit fox, swift fox, marten, muskrat, and ringtail (*Bassariscus astutus*).

We obtained substantive population density and sustainable yield rate estimates among ecozones for only bobcat (low ranked) and red fox (high ranked). Fragmented demographic information from technical literature for bobcat demonstrated the dearth of information for even a relatively well-documented furbearer (Table 5). Density and sustainable yield rate values for a specific ecozone were available only for bobcat in Juniper Savanna ecozone (Bluett and Tewes 1988).

Estimates of sustainable extraction thresholds for red fox and bobcat were extremely variable due to variation in minimum and maximum population density estimates (Tables 6 and 7). For red fox, minimum sustainable extraction thresholds ranged from 2,933 in Subalpine Coniferous Forest ecozone to 8,712 in Coniferous and Mixed Woodland ecozone (Table 6). Maximum thresholds were 50% larger (this difference is proportional to the minimum and maximum densities). The sustainable yield rate used in the calculation was the most conservative found in the literature. The overall sustainable extraction threshold for red fox (summed thresholds from Table 6 for all ecozones) ranged from a minimum of 20,718 to a maximum of 31,210.

Minimum sustainable extraction thresholds for bobcat ranged from 11 in Lava Beds ecozone to 394 in Coniferous and Mixed Woodland ecozone within this species' estimated distribution (Table 7). Maximum threshold estimates were much larger than minimum estimates within ecozones because of the 54-fold difference between maximum and minimum density estimates derived from technical literature. Summing the minimum and maximum threshold values (Table 7), respectively revealed that overall sustainable extraction estimates for bobcat ranged from 1,156 to 62,415 statewide.

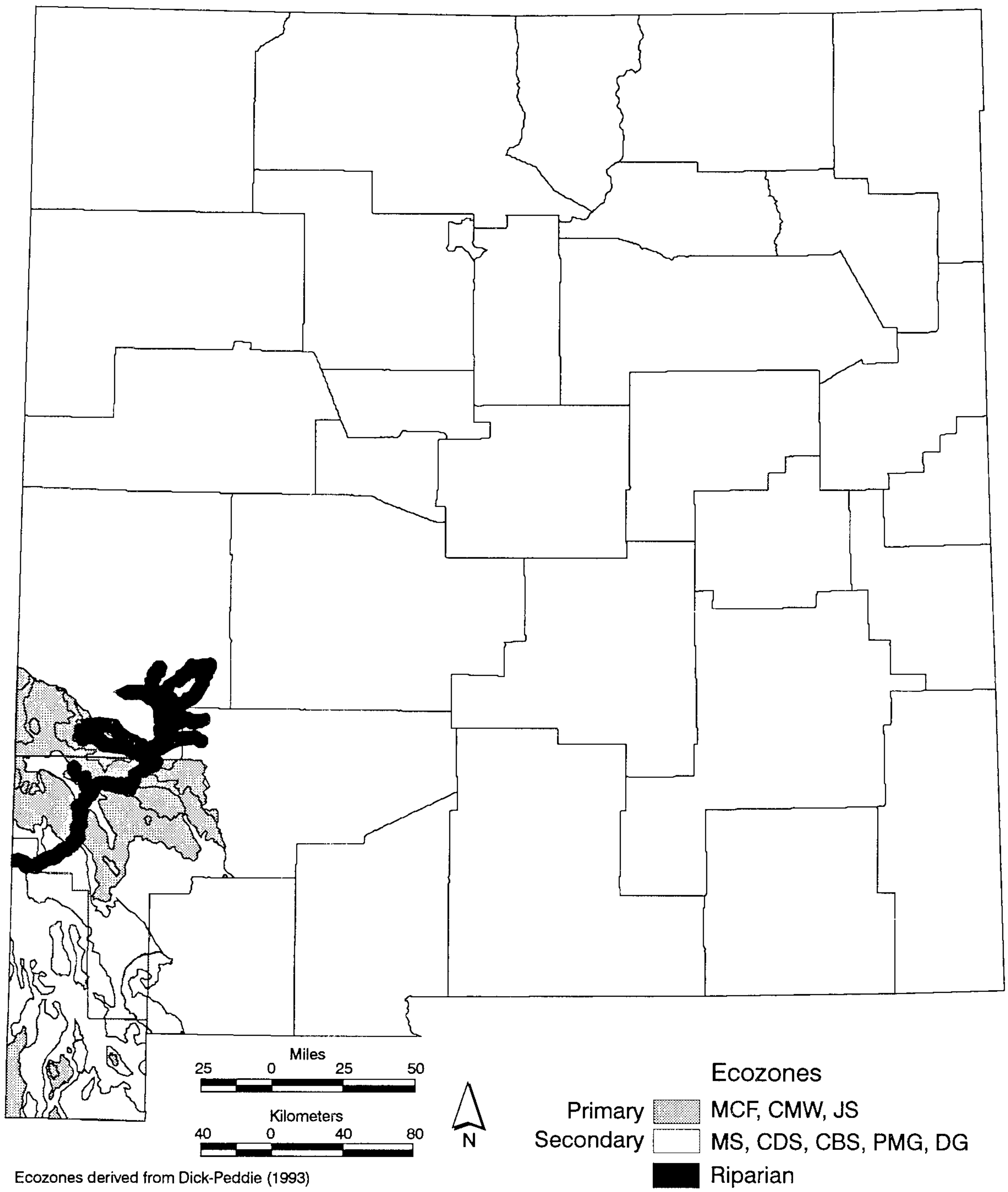

Fig 3. Estimated distribution of primary (including riparian buffer) and secondary habitat for coati (*Nasua nasua*) in eight New Mexico ecozones as derived from literature, museum records, and the 1991-92 observation and roadkill survey. (Ecozone abbreviations are defined in Table 1.)

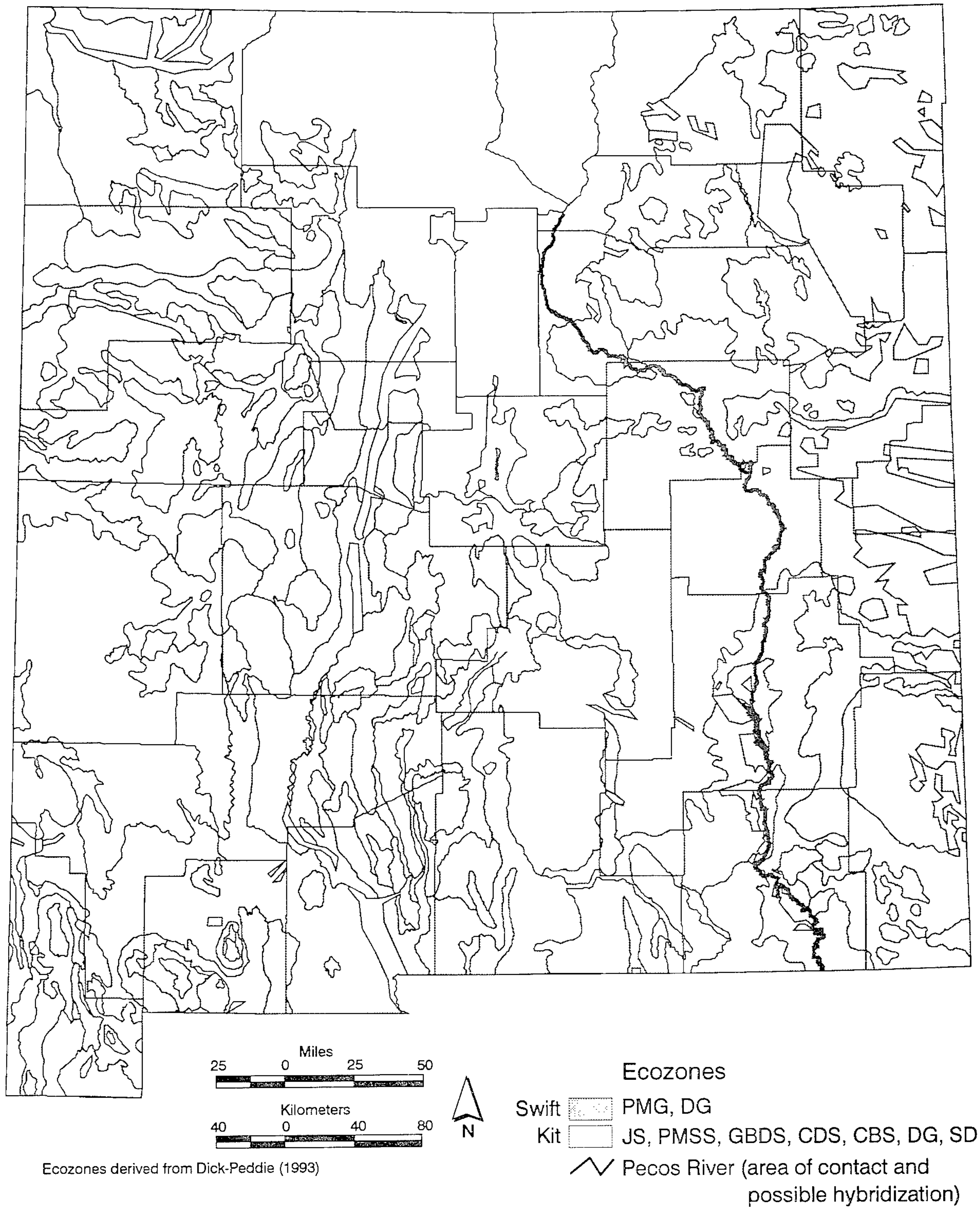

Fig 4. Estimated distribution of primary habitat for desert foxes (kit fox [*Vulpes macrotis*] and swift fox [*Vulpes velox*]) in eight New Mexico ecozones as derived from literature, museum records, and the 1991-92 observation and roadkill survey. (Ecozone abbreviations are defined in Table 1.)

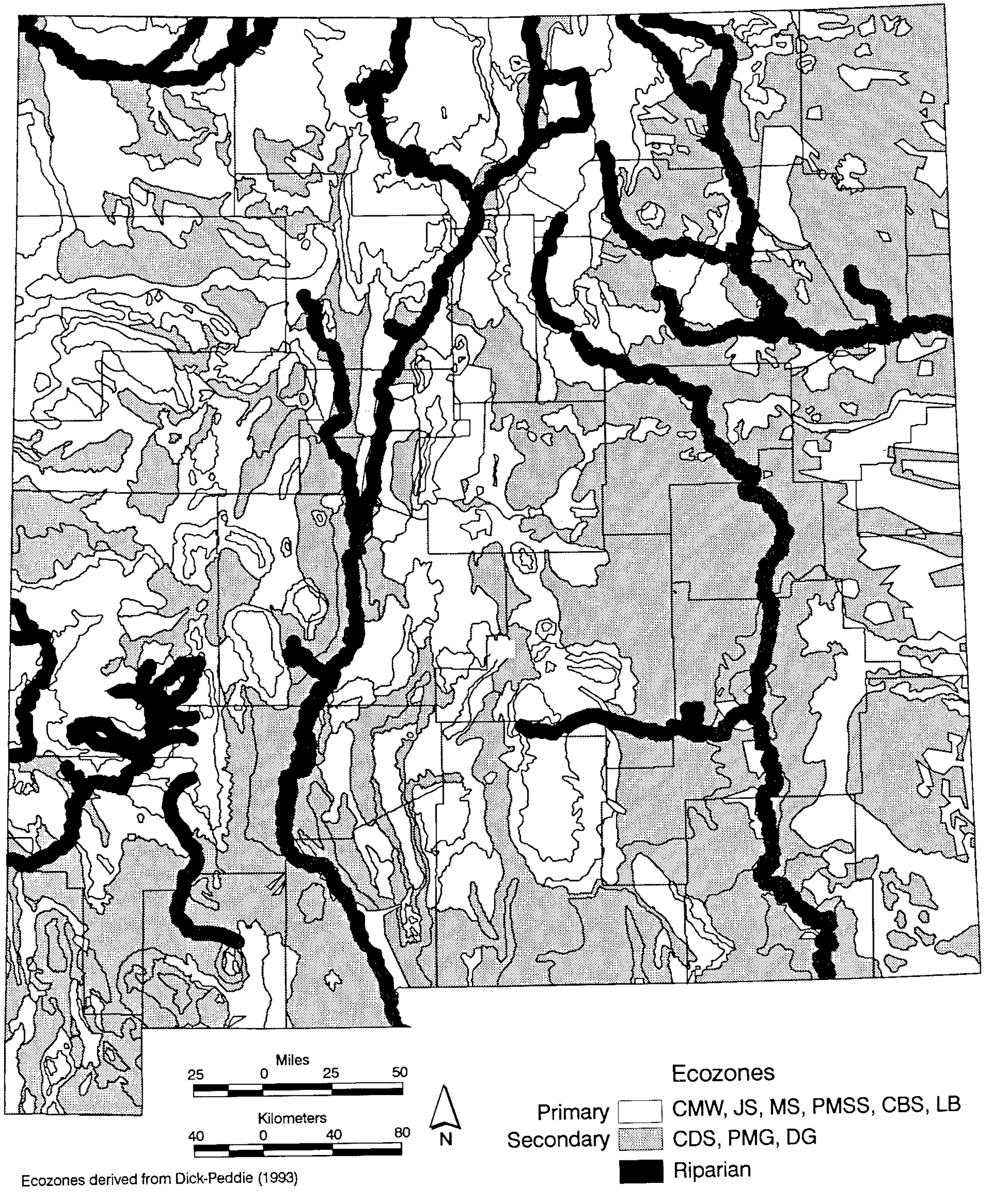

Fig 5. Estimated distribution of primary (including riparian buffer) and secondary habitat for gray fox (*Urocyon cinereoargenteus*) in nine New Mexico ecozones as derived from literature, museum records, and the 1991-92 observation and roadkill survey. (Ecozone abbreviations are defined in Table 1.)

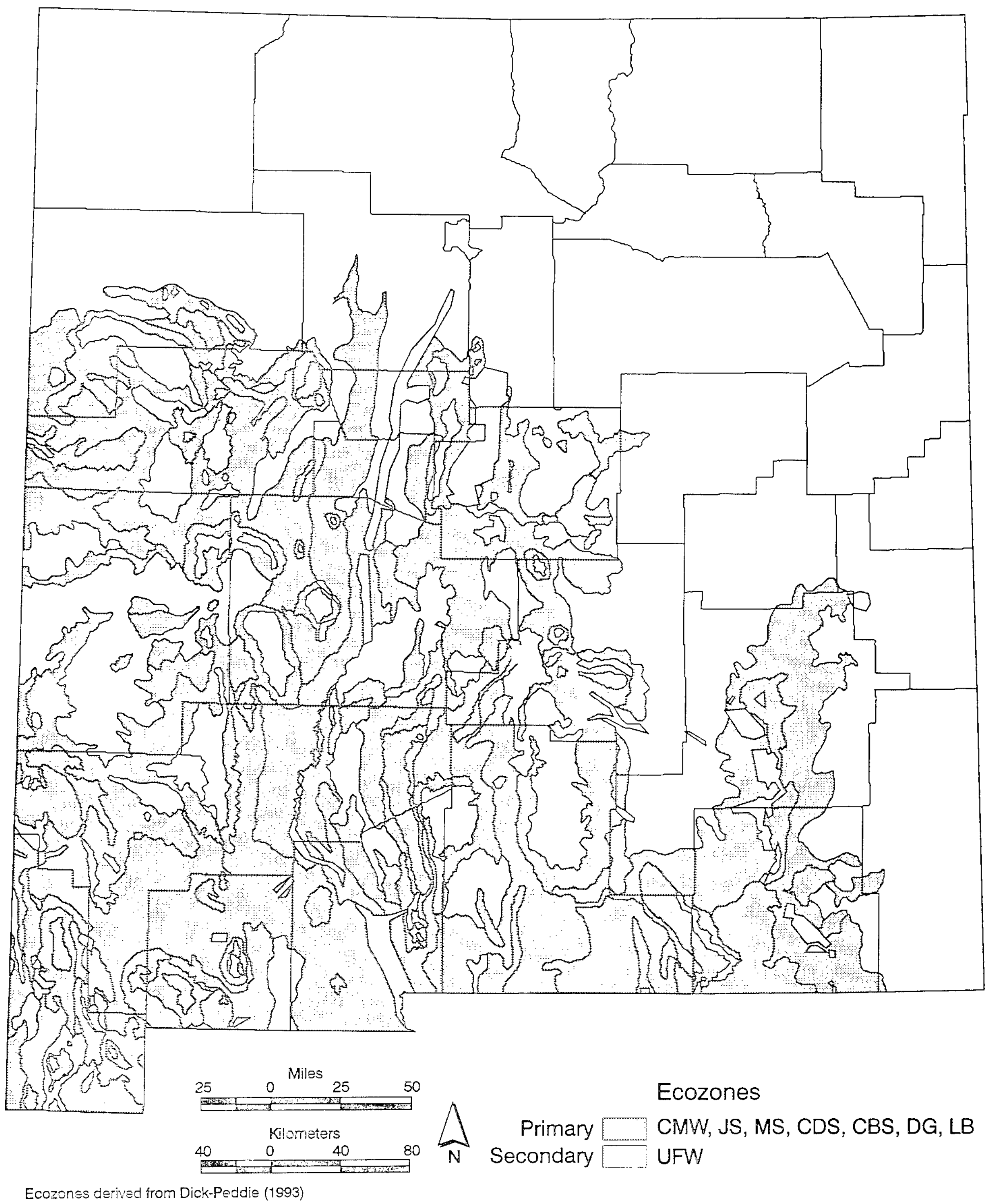

Fig 6. Estimated distribution of primary and secondary habitat for hog-nosed skunk (*Conepatus mesoleucus*) in eight New Mexico ecozones as derived from literature, museum records, and the 1991-92 observation and roadkill survey. (Ecozone abbreviations are defined in Table 1.)

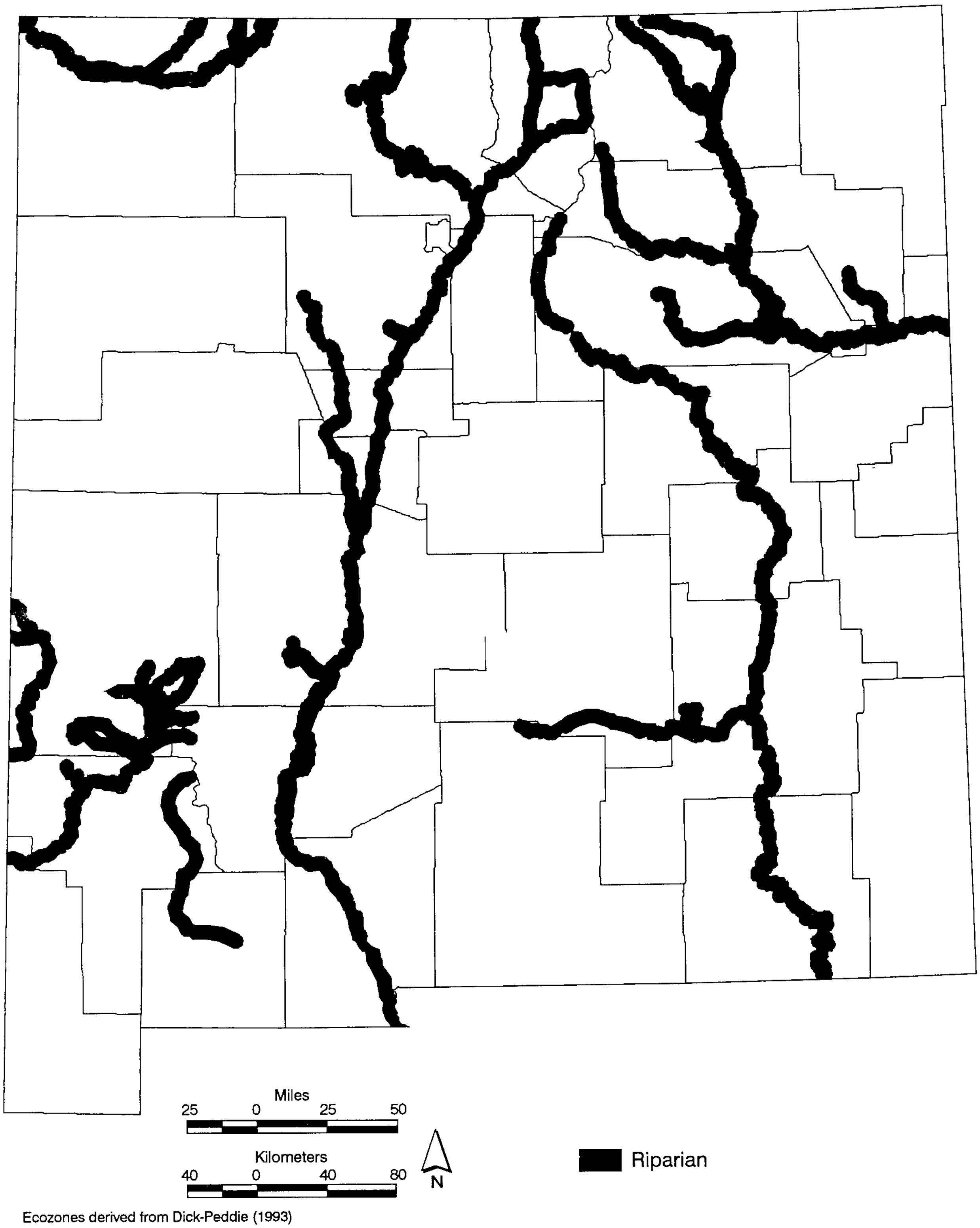

Fig 7. Predicted riparian zone associated with distribution of raccoon (*Procyon lotor*) in New Mexico as derived from literature, museum records, and the 1991-92 observation and roadkill survey.

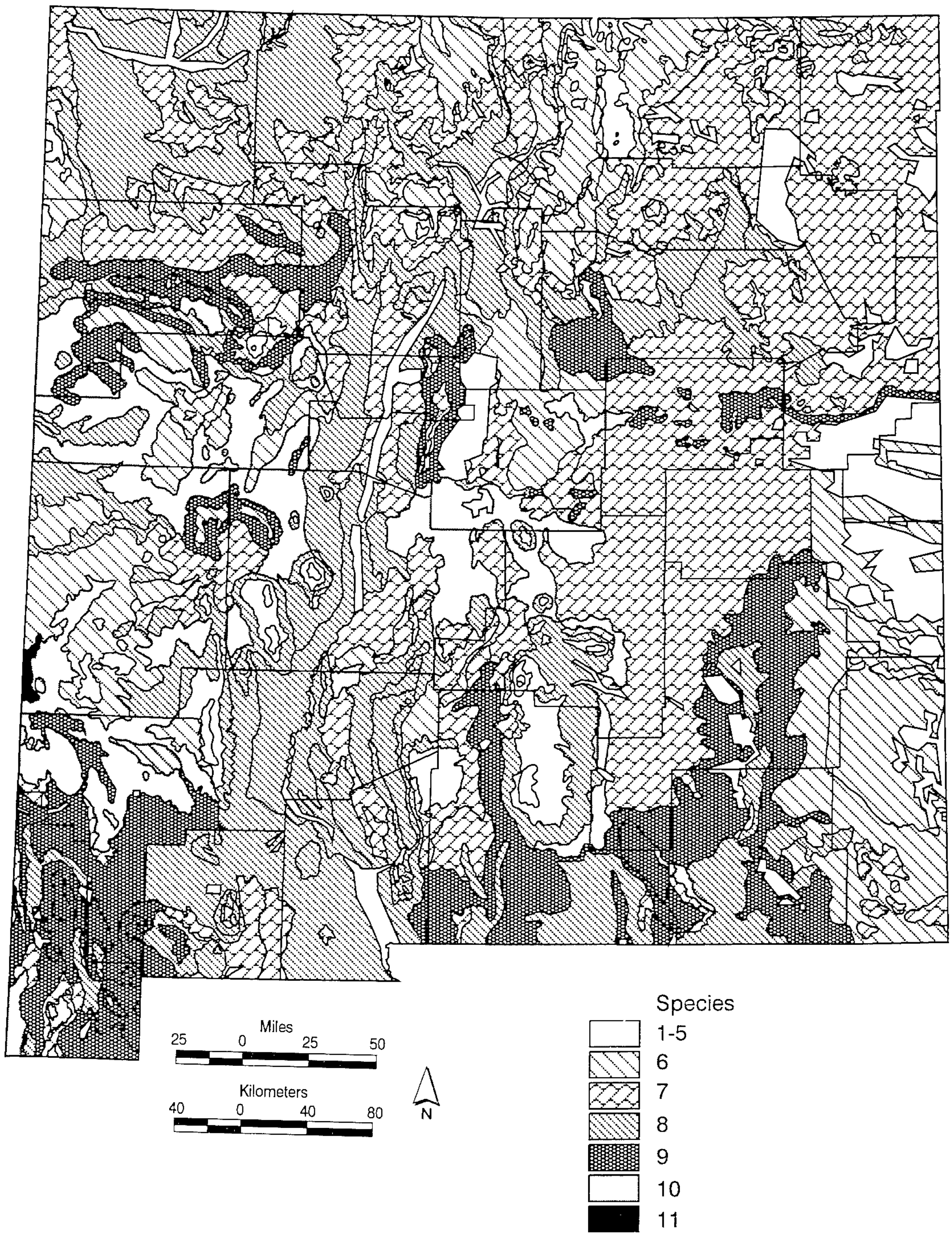

Fig 8. Patterns of furbearer species richness among various sized tracts representing 16 ecological zones in New Mexico.

Table 4. Estimated area of primary occupied habitat of 23 furbearer species in 16 ecozones (km^2) in New Mexico and extent of major riparian zones (linear km) calculated from geographic information system data bases.

	Estimated area of primary habitat by ecozone[a]																	
	AT	SCF	MCF	CMW	JS	MS	PMSS	GBDS	CDS	CBS	MG	PMG	DG	UFW	LB	SD	Statewide	Riparian (km)
Total ecozone area (km^2)	297	8,756	23,609	41,470	30,939	3,106	17,059	12,598	18,845	7,539	1,014	69,868	55,233	19,000	1,190	955	311,478	
Badger					30,939		17,059	12,598	18,845	7,539		69,868	55,233				212,081	
Beaver																	0	3,603
Bobcat		8,756	23,609	41,470	30,939	3,106		12,598							1,190		121,668	
Coati		193	1,685	5,612	221								17				7,728	
Coyote	297	8,756	23,609	41,470	30,939	3,106	17,059	12,598	18,845	7,539	1,014	69,868	55,233	19,000	1,190	955	311,478	
Ermine		7,280	9,672			59					617						17,628	
Fox, gray				41,470	30,939	3,106	17,059			7,539					1,190		101,303	
Fox, kit					24,799		16,707	9,862	18,845	6,594			53,957				130,764	
Fox, red		7,618	10,518	22,628										13,045			53,809	
Fox, swift												60,391	17,031	11,477			88,899	
Marten	234	5,971															6,205	
Mink																		1,720
Muskrat																		3,451
Nutria																	0	
Opossum																		422
Otter, river																	0	
Raccoon																		19,467
Ringtail				41,470	30,939	3,106		12,598	18,845			69,868	55,233				232,059	
Skunk, hog-nosed				22,880	19,187				18,845	7,539			44,768		1,116		114,335	
Skunk, hooded				5,607					3,632	1,079		105	9,089				19,512	
Skunk, spotted			23,609	41,470	30,939		7,731	12,598	18,845			61,397	53,926				250,515	
Skunk, striped			23,609	41,470	30,939	3,106	17,059	12,598	18,845	7,539		69,868	55,233	19,000	1,190		300,456	
Weasel, long-tailed	297	8,756	23,609	41,470	30,939	3,106			18,845		1,014	69,868	55,233	19,000			272,137	

[a]Ecozone abbreviations are defined in Table 1.

Table 5. Demographics of the bobcat (*Lynx rufus*) in three New Mexico ecozones that illustrate the lack of information for a commonly documented species.

Parameters		Demographics by ecozone[a]			
		MCF	CMW	JS	GEN
Males:females	min[b]		1.2:1	0.97:1	0.70:1
	max[b]		1.2:1	2.60:1	2.7:1
Adult pregnancy (%)	min				92
	max				92
Juvenile pregnancy (%)	min				46
	max				46
Litter size	min	2.86	1.67		2.3
	max	2.86	1.67		5.0
Fecundity[c]	min				1.02
	max				1.02
Juvenile survival (%)	min				9
	max				74
Adult survival (%)	min		72		46
	max		72		84
Recruitment (%)	min				1.02
	max				1.02
Fall density (animals/km^2)	min		0.058	0.2	0.05
	max		0.058	0.4	2.7
Sustainable yield (%)	min			19	19
	max			19	19
Estimated habitat (km^2)		23,609	41,470	30,939	

[a]Montane Coniferous Forest (MCF), Coniferous and Mixed Woodland (CMW), Juniper Savanna (JS), and general (GEN).
[b]Minimum and maximum values for each variable as derived from literature review.
[c]Number of female offspring per female.

Table 6. Demographic and sustainable extraction threshold (SET) estimates for red fox (*Vulpes vulpes*) in four New Mexico ecozones based on technical information available through 1992.

Demographic parameters		Estimates among ecozones[a]			
		SCF	MCF	CMW	UFW
Estimated habitat (km^2)		7,618	10,518	22,628	13,045
Density[b]	min[c]	0.77	0.77	0.77	0.77
	max[c]	1.16	1.16	1.16	1.16
Population estimate	min	5,866	8,099	17,424	10,045
	max	8,837	12,201	26,248	15,132
Sustainable yield (%)		50	50	50	50
SET[d]	min	2,933	4,050	8,712	5,023
	max	4,419	6,101	13,124	7,566

[a]Subalpine Coniferous Forest (SCF), Montane Coniferous Forest (MCF), Coniferous and Mixed Woodland (CMW), and Urban, Farmland, and Water (UFW) ecozones.
[b]Technical literature suggested that similar values (foxes/km^2)can be applied across ecozones.
[c]Minimum and maximum values for each variable as derived from literature review.
[d]Wide ranges in threshold values reflect variation in densities.

Table 7. Demographic and sustainable extraction threshold (SET) estimates for the bobcat (*Lynx rufus*) in seven New Mexico ecozones calculated using demographic parameter estimates derived from technical literature review.

Demographic parameters		SCF	MCF	CMW	JS	MS	GBDS	LB
Estimated habitat (km^2)		8,756	23,609	41,470	30,939	3,106	12,598	1,190
Density[b] (animals/km^2)	min	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	max	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Population estimate	min	438	1,180	2,074	1,547	155	630	60
	max	23,641	63,744	111,969	83,535	8,385	34,015	3,213
Sustainable yield (%)		19	19	19	19	19	19	19
SET[c]	min	83	224	394	294	30	120	11
	max	4,492	12,111	21,274	15,872	1,593	6,463	610

[a]Subalpine Coniferous Forest (SCF), Montane Coniferous Forest (MCF), Coniferous and Mixed Woodland (CMW), Juniper Savanna (JS), Montane Scrub (MS), Great Basin Desert Scrub (GBDS), and Lava Beds (LB) ecozones.
[b]Technical literature suggested that similar values can be applied across ecozones.
[c] Wide range in threshold values demonstrates the variation in densities.

Past harvest estimates ranged from well below presumed thresholds to extraction in excess (maximum estimated bobcat harvest relative to minimum thresholds) of thresholds (Table 8). We did not judge these threshold estimates to be suitable to support furbearer management decisions as they are based on literature of variable quality and resolution. Sustainable extraction thresholds are meaningful only when demographics are known with a higher degree of confidence.

Harvest Survey Performance

Survey Response

We surveyed 755 of the 800 people who bought trappers licenses for the 1991-92 season. The number of licensees included in each survey type and the approximate cost per usable response were 48 journal ($7.50), 472 mail ($8.50), 118 telephone ($13.75), and 117 personal interviews ($47.75).

Response rates differed markedly among survey types, and reported harvest differed between those responding to the first contact and those responding to follow-up contact (Table 9). Overall, we received responses from 414 of 755 (54.8%) licensees surveyed in the initial samples for all survey types.

Harvest Survey Results

Analysis of variance indicated reported harvest for bobcat, coyote, gray fox, and raccoon differed ($F = 4.66$, 3,410 df, $P < 0.01$) among survey types. The more personal survey types had the highest variability for 10 of the 12 species (ringtail and hog-nosed skunk were exceptions) that were reported in three or more survey types. Coefficient of variation on harvest estimates for 12 species averaged 0.44 for mail survey, 0.50 for telephone survey, and 0.50 for personal interview. This higher variability suggests that upper and lower bounds of individual harvest

Table 8. Total red fox (*Vulpes vulpes*) and bobcat (*Lynx rufus*) sustainable extraction thresholds (SET) compared with estimated harvest for New Mexico, 1980-88.

	SET		Estimated harvest[a]		
Species	min	max	min	max	mean
Bobcat	1,156	62,416	1,172	3,584	2,508
Fox, red	20,718	31,210	89	819	404

[a] From 1980-88 New Mexico Department of Game and Fish unpublished reports.

Table 9. Response rates and average reported harvest per respondent for 17 furbearer species from four surveys of New Mexico trappers licensees, 1991-92 fur season.

	Average reported harvest per respondent								
	Mail survey			Phone survey		Personal interview		Journal	
	First mail	Second mail	Phone contact[b]	Phone	Mail contact[b]	Personal interview	Mail contact[b]	Journal	Phone contact[b]
N[a]	439	361	87	118	45	117	59	48	26
% Response	25.5	26.0	25.3	56.8	26.7	47.0	16.9	45.8	76.9
Badger	0.45	0.16	0.09	0.10		0.67	0.50	0.50	
Beaver	1.48	0.33	0.05	0.03		0.62			0.10
Bobcat	1.37	0.37	0.41	0.83	1.33	0.93	1.10	0.36	0.45
Coyote	9.93	3.66	1.23	5.47	10.41	9.32	9.10	4.23	4.75
Ermine				0.01		0.02			
Fox	0.21	0.11			1.58		0.10	0.05	
Fox, gray	2.36	2.09	0.14	2.50	0.08	2.18	0.30	0.73	3.25
Fox, kit	0.23	0.17		0.33		0.18	1.50	0.55	
Fox, red	0.02			0.42		0.05	0.10		0.05
Fox, swift	0.32	0.06				1.04	0.60		
Muskrat	5.85	0.28		0.19	2.92	1.27	1.10		1.25
Nutria				0.24					
Raccoon	0.97	0.57	0.05	1.25	0.58	1.40	1.30	0.23	0.85
Ringtail	0.14			1.09		0.64	0.10		
Skunk	0.18	0.33			0.83	1.29			
Skunk, hog-nosed	0.01	0.13		0.09			0.20		
Skunk, hooded	0.02								
Skunk, spotted	0.01		0.14	0.09					
Skunk, striped	0.89	0.13		1.85	0.25	0.42	1.50	0.27	

[a]N is the actual number of licensees successfully contacted, corrected for undeliverable addresses and erroneous telephone numbers.
[b]Represents follow-up contact after nonresponse in primary category of survey.

may have been detected more accurately by personal surveys. Because the licensees were surveyed by different types of surveys, sample sizes were insufficient to estimate harvest among ecozones. Estimates among ecozones would be possible if licensees were subjected to a single survey type.

Despite detectable differences in estimates among survey types, there were no pronounced differences that identified any one survey as best for comparison to sustainable extraction threshold estimates. Discounting the journal survey because of its small sample, statewide estimates of harvest for four widely harvested species based on mail, telephone, and personal interview surveys had confidence limits within similar general bounds (Fig. 9). Although personal contact surveys appear to produce generally larger estimates, which would trigger management attention sooner, a mail survey with a second mailing and telephone follow-up appear satisfactory for estimating harvest.

Comparison of Harvest with Species Distribution

A matrix of reported harvest for 17 species by ecozone revealed some deviations from our predictions of species occurrence (Fig. 10). On our species distribution maps, there were 153 ecozone-species combinations (111 primary, 42 secondary) in which harvest could be expected. Of these, harvest was reported for 85 (55.6%) matrix cells, including 62 primary ecozone-species combinations and 23 secondary ecozone-species combinations. There was no reported harvest in the remaining 49 primary and 19 secondary ecozone-species combinations. Lack of reported harvest in 44.4% of the expected cells indicated that harvest activities have not been directed at the entire predicted population distribution of some species, that licensees did not report all harvest, or that animals are not present in some of the predicted areas (e.g., badger, ringtail, spotted skunk, long-tailed weasel; Fig. 10).

We found species distribution to be generally consistent with reported harvest, and harvest reported from unexpected areas was generally explainable. Harvest was reported in 19 (16.0%) of the 119 species-ecozone combinations we classified as unoccupied habitat (Fig. 10). Matrix cells related to the Urban, Farmland, or Water (UFW) ecozone and to riparian species (beaver, muskrat, and

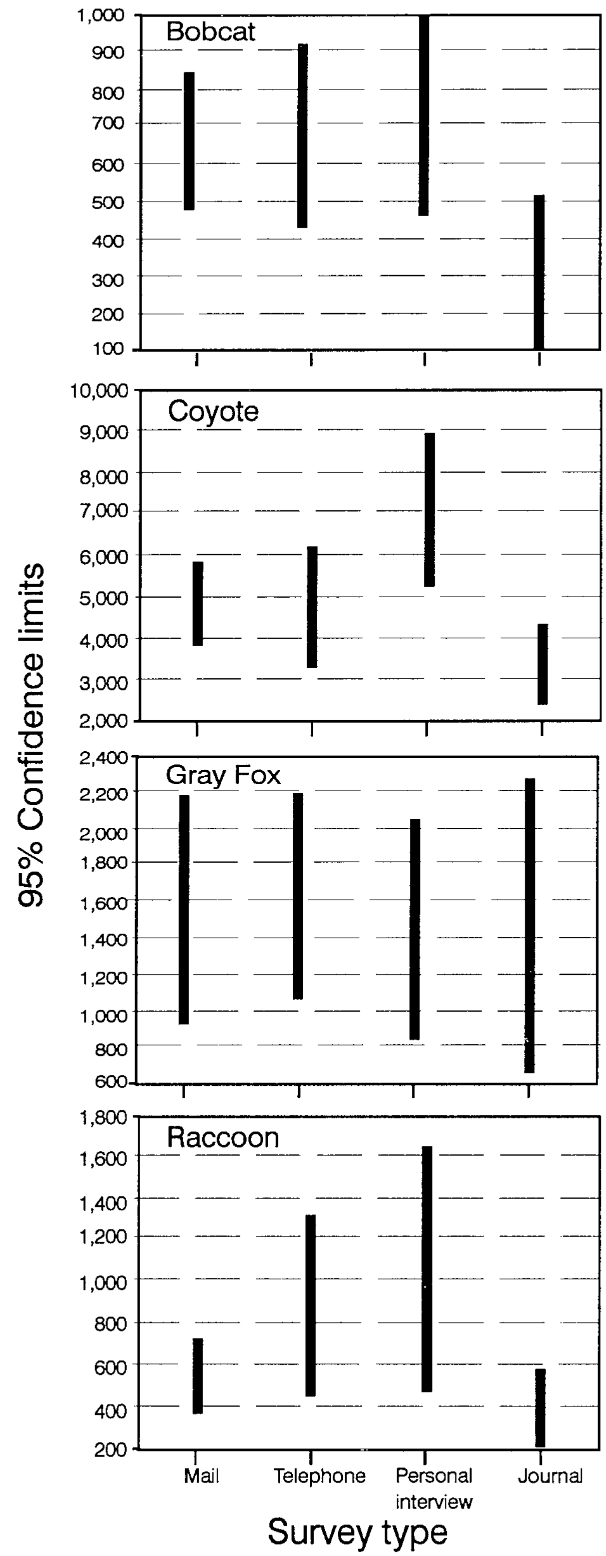

Fig 9. Harvest estimates with 95% confidence limits for bobcat (*Lynx rufus*), coyote (*Canis latrans*), gray fox, (*Urocyon cinereoargenteus*), and raccoon (*Procyon lotor*) for four surveys of trappers licensees in New Mexico, 1991-92 furbearer season.

Species	Reported Harvest by Ecozone																
	AT	SCF	MCF	CMW	JS	MS	PMSS	GBDS	CDS	CBS	MG	PMG	DG	UFW	LB	SD	Unknown	Total
Badger		7		19	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	5			25	128
Beaver				20									6	210				236
Bobcat		[illegible]	[illegible]	[illegible]	[illegible]		16		31	5		17	71	3			93	352
Coyote	[illegible]	[illegible]	[illegible]	195	263	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	825	2,801
Ermine		[illegible]	[illegible]		1						[illegible]							2
Fox, gray			30	[illegible]	[illegible]	[illegible]	[illegible]		82	[illegible]	4	86	56	54	[illegible]		280	859
Fox, desert		10		11	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	13	1	[illegible]	21	207
Fox, red		[illegible]	[illegible]	[illegible]	22	4	1	1				1		[illegible]				35
Muskrat													70	[illegible]			35	837
Nutria												5		[illegible]				16
Raccoon		1	9	3	4				5			6	36	[illegible]			85	372
Ringtail			1	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	8		[illegible]	[illegible]	[illegible]			3	127
Skunk, hog-nosed									[illegible]	[illegible]				3			12	21
Skunk, hooded														2				2
Skunk, spotted														8				10
Skunk, striped			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]			[illegible]	[illegible]	[illegible]			48	313
Weasel, long-tailed																		0

Fig 10. Harvest among 16 ecozones for 17 furbearer species as reported by respondents to 1991-92 trappers licensee survey in New Mexico. Species by ecozone cells are classified as primary habitat (dark gray), secondary habitat (light gray), and unsuitable habitats (white). Riparian harvest is included in the water component of the Urban, Farmland, or Water ecozone. (Ecozone abbreviations are defined in Table 1.)

nutria)accounted for 7 (36.8%) of these 19 combinations. These discrepancies were not surprising because our mapping and harvest survey were not detailed enough to effectively account for animals taken in linear habitat adjacent to a variety of ecozones or contained within the generalized UFW ecozone. Generally, less than 15% of a species' overall reported harvest related to inconsistent cells in the matrix; rarer species such as ermine and spotted skunk were exceptions. Also, nutria harvest was reported in two ecozones, although we previously were unable to reliably predict distribution because recent verified specimen records were limited. These exceptions involved few animals in total (14 among the 3 species) and represent minor discrepancies for species that are sought much less by licensees, thus reducing management implication.

Review of Additional Considerations

Species Distribution in Ecozones

Our species distribution maps incorporated county-based specimen records and species habitat preferences. This use of species-by-county records does not conflict with a goal of reducing dependence on political boundaries for wildlife management practices. Species occurrence records are a valuable resource and are typically tallied by county. By relating county records to suitable habitat, we linked the concept of ecologically based distribution to political boundary-based data sets.

Most studies of furbearers have focused on species that are a threat to human interests or are of economic importance (Allen 1987). Much of the literature reviewed was either too general to apply to an ecozone or was specific to such small study sites that extrapolation to larger areas was uncertain. A more generalized ecological classification with fewer zones could partially overcome this problem. However, our review indicated that information would still be limited and managers should not risk early overgeneralization at the expense of exploring potential for focused, detailed investigation. We expect these conditions to prevail in other regions as well, but acknowledge the need for making management decisions with limited information. Need for such decisions should not preclude strategic program planning at a finer scale.

Mapping furbearer distribution based on vegetation zones may be an oversimplification because of the carnivorous nature of some furbearers. Armstrong (1982) indicated that carnivores tend to be less restricted in their range of habitats than herbivores and search for prey among community types, sometimes wandering widely. The influence of prey on furbearer distribution is documented in technical literature (badger [Messick 1987], ermine [Fagerstone 1987], kit fox [Schmidly 1977], red fox [Findley 1987], and marten [Strickland et al. 1982]). If a correlation between principal prey and predators were found, prey distribution could be used as an additional indicator of predator distribution. Allen (1987) also discussed the differences in habitat size and use for primary and secondary consumers. His key point was that carnivores need a large area of habitat to provide an ample prey base. This suggested that vegetation zones alone might not provide a sufficient basis to map distribution of carnivorous furbearer species. However, general animal-habitat relationships such as we used are deemed useful despite the acknowledged complexity in how animals select habitat (Morrison et al. 1992).

Demographic Information Base

Accurate sustainable extraction thresholds can be calculated only if population densities and sustainable yield rates are known. This demographic information was not widely available for most species, and it was not available for species at an ecozone level. Publications often referred to the lack of demographic details for species such as coati and ringtail (Kaufmann 1987), gray fox (Fritzell 1987), red fox (Samuel and Nelson 1982), swift fox (Jones et al. 1987; Scott-Brown et al. 1987), opossum (Gardner 1982), hog-nosed skunk (Rosatte 1987), and hooded skunk (Godin 1982; Rosatte 1987). Substantial research is needed before furbearer demographics are reasonably understood on an ecozone basis.

Validity of Sustainable Extraction Thresholds

The thresholds we estimated for red fox and bobcat were based on information from technical literature. Actual sustainable extraction levels for either species might be quite different from the calculated thresholds. These thresholds, however, are useful to indicate our current level of knowledge and where improved data are needed to set biologically based harvest objectives.

Accuracy of sustainable extraction thresholds reflected the variability of population densities and sustainable yield rates reported in literature; the wide ranges of these values resulted in imprecise threshold estimates of unknown accuracy. Density estimates for the bobcat ranged from 0.05 to 2.7 bobcats/km^2 (Table 7). Some authors cited extremely low or extremely high densities in isolated populations (Knick 1990). Such values are not necessarily realistic minimum or maximum estimates for a population over a large area. Applying a density estimate derived for an isolated population, as we did for some species, will bias the sustainable extraction estimate.

Regardless of how the sustainable yield rate is derived, it should be conservative because of variability in the rate of increase. Sustainable yields are very complex functions of past and present conditions. A deterministic sustainable extraction threshold represents a simplification of the sustainable yield concept (Caughley 1977). If an extraction threshold is too high and relatively insensitive to stochastic events, excessive removal could occur before conservation attention was triggered. As an example, the only sustainable yield rate reported for red fox was 50% (Clark and Fritzell 1992) and may not apply to New Mexico. Also, this number might be too high because 25% was the smallest sustainable yield rate for the biologically similar gray fox (Fritzell 1987; Voigt 1987). The higher rate of 50% might not be sustainable over a long term.

Variability in Harvest Survey

We could not determine which survey type was most accurate because the actual harvest was unknown. If variability of reported harvest signifies that the extreme values are represented, then the survey with the highest variability should best portray the actual harvest. Telephone surveys and personal interviews had the most variability in reported harvest for 10 of the 12 species that were reported in three of the four survey types. The telephone survey and the personal interview also resulted in the largest harvest estimates for 14 of the 17 species. Larger harvests reported by individual telephone survey respondents for some species had implications for management; higher reported harvests trigger management attention sooner.

Consistency of Reported Harvest with Species Distribution

The harvest survey provided a means to evaluate the validity of our species distribution maps. In some cases, harvest was reported for species in ecozones that were not classified as habitat. In other cases, no harvest was reported for species in ecozones in which we expected to find the species. Some possible reasons for these outcomes include: (1) primary and secondary habitat classifications could be wrong; (2) harvest reports reflect locations and characteristics of licensees, not necessarily species density or distribution (Thompson et al. 1992a); (3) areas thought to be unoccupied by a species might actually be secondary habitat; (4) location of harvest could be inaccurately reported by licensees; (5) harvest effort is not applied evenly throughout the distribution of each species; or (6) harvest location is influenced by fur market (Erickson and Sampson 1978).

Reported harvest that was inconsistent with expected species distribution generally involved riparian species and the Urban, Farmland, or Water ecozone. This pattern involved 37% of inconsistent reports and 70% of the 251 harvested animals reported for unexpected species-ecozone combinations. The Urban, Farmland, or Water ecozone probably is an over-generalized land cover category that includes habitat features not all used by some species.

Interpreting a Management Matrix

The matrix (Fig. 10) can be useful in management. If sustainable extraction thresholds (could be exploratory values) and estimates of harvest were provided for each cell, wildlife managers would have a workable ecologically based management framework in a single image. Annual update and comparison of the numbers would indicate which species are probably used within sustainable limits and which may need review of management efficacy. Maintaining this approach in spreadsheet or GIS format would ease periodic updating and iterative reviews of the management process by manipulating variable values based on newly obtained data. Such a matrix as a management guide is only as effective as the scale and accuracy of distribution mapping and harvest estimation allows. Species that occur in large or irruptive populations in localized areas (e.g., beavers in canals) are not fully represented in this format.

Feasibility of the Ecological Framework

Our research revealed a process for developing an ecological framework for wildlife management (Fig. 11). We showed how far this process can go for New Mexico furbearers at this time. We selected an ecological map that corresponds well to furbearer habitat, described species habitat in terms of vegetation-based ecozones, developed species distribution maps, and developed a tool for use by wildlife managers to evaluate furbearer harvest. This represents four of the five steps we deemed necessary for an implementable framework (see section on Components of the Ecological Framework). With increased demographic information, improved sustainable extraction thresholds (fifth step) could be calculated, although the time and complexity involved in testing hypotheses about sustainable yield are imposing. This process would then provide a complete framework for wildlife professionals to assess harvest of furbearer resources or other species subject to consumptive use.

When based on ecozones rather than political boundaries, wildlife management is more relevant to many factors that affect the sustainability of a species (Shaw 1991; Kessler et al. 1992). The underlying principles are sound and applicable to organizing multiple species management elsewhere. Such an approach can complement priority setting based on other factors such as animal damage to agricultural products (Wywialowski 1994). Establishing conservation priorities for wildlife is an acknowledged need (Millsap et al. 1990).

Resource management professionals must assess the feasibility of establishing an ecological framework for management of multiple species complexes on a case-by-case basis. They must decide how generalized demographic information can be and still meet needs for managing a public trust resource. Averaged or regional demographic estimates associated with simpler ecological subdivisions might meet the needs of some managers. This generalization could reduce information requirements while allowing scaling consistent with species-specific management strategies and geographic responsibilities of agencies. Regardless of the scale or strategy selected, we submit that having some framework that systematically organizes known and needed information on availability versus use within ecologically described confines is the only defensible position for managing extractive use of renewable wildlife resources in the future. This is an important underpinning of sustainable development as discussed by Primack (1993) and Meffe and Carroll (1994).

Management Implications

Our research may be used as a guide for wildlife managers seeking an ecologically based perspective for managing single or multiple species complexes. We developed significant ecological perspective on species distribution, demographic data, and extraction estimates. Falsification of the hypothesis regarding presumed sustainable harvest reflected deficient demographic information rather than intractability of an ecologically based management framework. The matrix generated from these data quickly identified unavailable data and indicated some priority areas for future demographic research. Importantly, this hypothesis test and associated information compilation openly illustrated the current foundation of a harvest program and the type of information necessary to strengthen that foundation.

Some potential implications of this work for enhancement of resource programs include:

- **Enhanced ability to examine current harvest programs relative to concepts of sustainable use**

  A goal of any extractive use program should be to assure long-term sustainable use of the harvested resource. Harvesting species at historic levels that appear consistent with available resources has worked for decades and may seem to meet such a goal, but it has little biologically quantified basis. We outlined ways to compile, organize, and analyze available information for a multiple-species complex to assess current knowledge relative to a quantified,

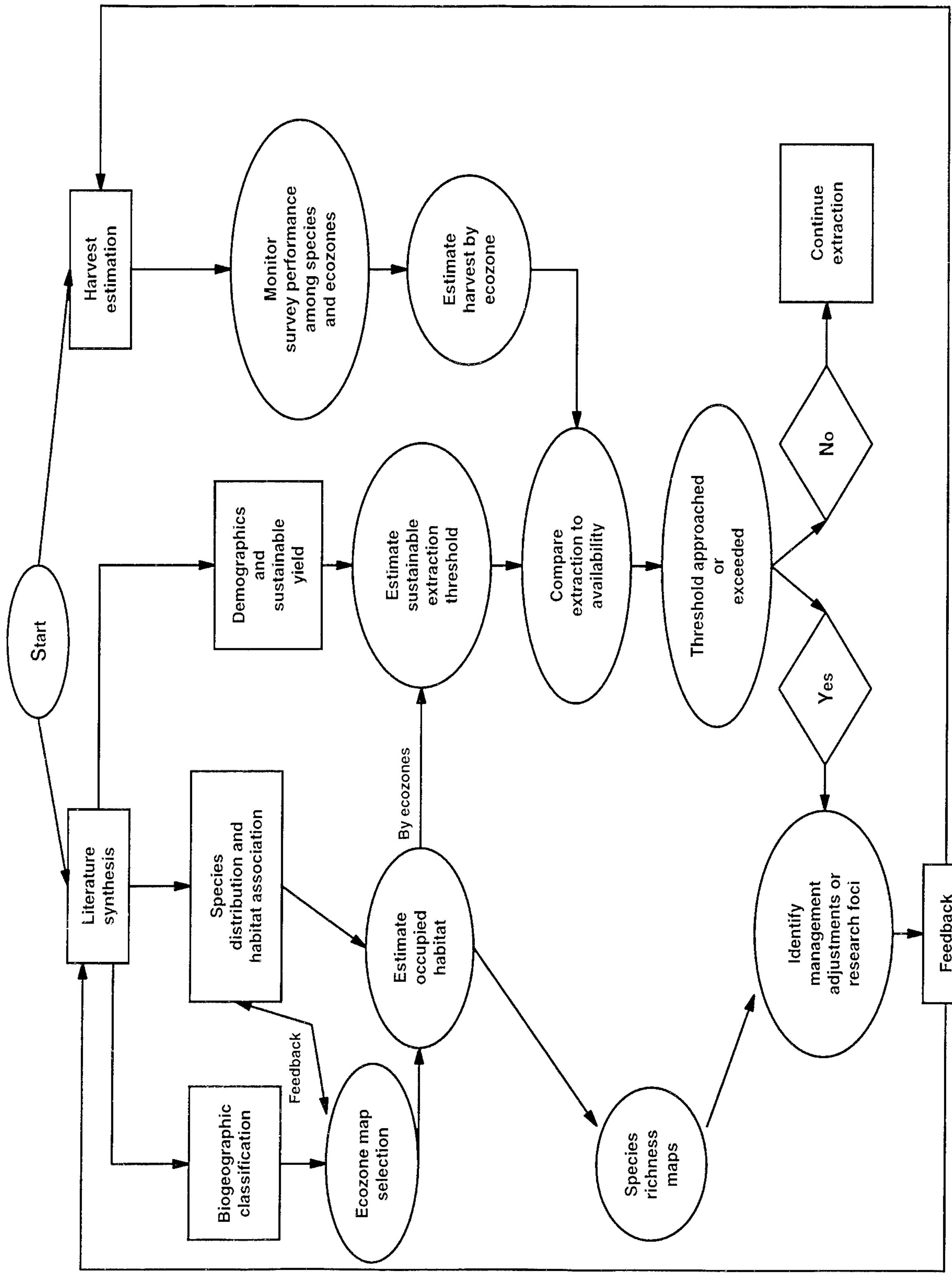

Fig 11. Conceptual diagram for an ecological framework to assess sustainable use of wildlife.

comprehensive, ecologically based understanding of this resource. Such a posture seems to be professionally advisable if extractive use programs are to be justified on a scientifically sound basis that acknowledges real information deficiencies.

- **Identification of conservation focus areas**

  A low population of a species statewide or in particular ecozones may also indicate the need for conservation attention. All heavily used harvest areas need to be examined more closely for species for which information is most limited. Our process identified focus areas to investigate multiple species in relatively confined locations.

- **Use of biological data sets in GIS format to assess management alternatives**

  Overlays of other biotic or socioeconomic data (such as land management categories) can be examined relative to species distribution in a process similar to that described for conducting gap analysis of biological diversity (Scott et al. 1993). These data layers, when overlaid on the ecozone base map, illustrate which ecozones may offer conservation opportunities or may provide more efficient management applications. Data availability in GIS format allows integration into broader computer applications and can facilitate the evaluation of management alternatives. Although our evaluation was primarily harvest based, our suggested data organization is applicable to other interests as well. For instance, this data synthesis could be used to estimate the effect of large-scale landscape alterations on wildlife or to supplement environmental impact assessments.

- **Detection of weak demographic information**

  Deficient demographic information is likely for species in other geographic areas, but the degree of limitation cannot be determined until existing information is synthesized. Although limited demographic data may be a fact accepted by most biologists, it need not diminish attempts to gain perspective on where the greatest information needs lie, so strategic study can be considered.

- **Opportunity for shared responsibility among resource jurisdictions**

  In a framework where resource units do not stop at political boundaries, responsibility for wildlife management does not either. A management approach based on ecological subdivisions encourages interagency and interjurisdictional sharing of responsibilities. This sharing is increasingly important where resource agencies are pressed to economize on staff and operating budgets. Our suggested approach to organizing information and deriving conservation perspectives is a simple process to apply and promotes benefits of interjurisdictional cooperation.

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